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Implementation and Testing of LTE Transmitter in Lab VIEW

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ABSTRACT

Long Term Evolution (LTE) is a prominent project of 3rd Generation Partnership Project (3GPP). LTE, as a revolution from the 3rd generation (3G) to the 4th generation (4G) cellular communication, has achieved great capacity and high speed of mobile telephone networks. It has defined a new packet-only wideband radio with flat architecture and assumes a full Internet Protocol (IP) network architecture in order to assure voice supported in packet domain in design. In addition to that, it is combined with top-of-the-line radio techniques in order to gain better performance than Code Division Multiple Access (CDMA) approaches. LTE uses OFDM (Orthogonal Frequency Division Multiplexing Access) technology which can provide high-degree resilience to reflections and interference at the same time. For the downlink OFDMA is used and for the uplink SC-FDMA (Single Carrier- Frequency Division Multiplexing Access) is used which has the advantages of smaller peak to average power ratio. In this paper, it is proposed to present the overall description of LTE technology and to simulate the LTE Transmitter using LabVIEW (v2017)software.

KEYWORDS: LTE, Downlink, Uplink, OFDMA, SC-FDMA, MIMO.

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INTRODUCTION:

Mobile communication has taken a huge turn in the world today. It is been discussed in terms of its generations. In the 1st generation mobile telephony, the technology used is analog in nature. In the 2nd generation, digital telephony has dominated the analog versions and played a vital role in the era of mobile communication. Coming to 3rd generation, the voice and data usage has given importance and the data rates have increased tremendously.

3G (3rd GENERATION)TECHNOLOGY

3G is the next generation of technology which has revolutionized the telecommunication industry. Apart from increasing the speed of communication, the objective of this technology is to provide various value added services like video calling, live streaming, mobile internet access, IPTV, etc on the mobile phones. These services are possible because the 3G spectrum provides the necessary and width.Technicallyspeaking3Gisanetworkprotocol which refers to the generations of mobile phones and telecommunication equipment which are compatible with the International Mobile Telecommunications-2000 (IMT-2000) standards stated by International Telecommunication Union (ITU). The basic requirement for compiling to IMT-2000 standards is that the technology should provide peak data rates of at least 200 kbit/s. 3G Technology is designed for multimedia communication.

One of its key visions is to provide seamless global roaming, enabling users to move across borders while using the same number and handset. According to ITU it is expected that IMT-2000 will provide higher transmission rates: a minimum speed of 2Mbit/s for stationary or walking users, and 348kbit/s in a movingvehicle.

1. Some applications or fields which were explored after the introduction of 3G are:
2. Making Remote Access Network Connectivity for small branches/temporary locations is simple and easy using 3GNetwork.
3. Reduce long distance call charges using VOIP Communications and 3G Network.
4. Video conferencing from anywhere in theworld.

3G is the third generation of mobile phone standards and technology, superseding 2G, and preceding 4G. It is based on the International Telecommunication Union (ITU) family of standards under the International Mobile Telecommunications programme, Additional features also include HSPA data transmission capabilities able to deliver speeds up to 14.4Mbit/s on the downlink and 5.8Mbit/s on the uplink. Spectral efficiency or spectrum efficiency refers to the amount of information that can be transmitted over a given bandwidth in a specific digital communication system. High-Speed Packet Access (HSPA) is a collection of mobile telephony protocols that extend and improve the performance of existing UMTSprotocols.

4G (4th GENERATION)TECHNOLOGY

In a world of fast changing technology, there is a rising requirement for people to communicate and get connected with each other and have appropriate and timely access to information regardless of the location of each individual. The increasing demands and requirements for wireless communication systems ubiquity have led to the need for a better understanding of fundamental issues in communication theory and electromagnetic and their implications for the design of highly-capable wireless systems.

LONG TERM EVOLUTION (LTE):

LTE, Long Term Evolution, the successor to UMTS and HSPA is now being deployed and is the way forwards for high speed cellular services. In its first forms it was a 3G or as some would call it a 3.99G technology, but with further additions the technology fulfilled the requirements for a 4G standard. In this form it was referred to as LTE Advanced. There has been a rapid increase in the use of data carried by cellular services, and this increase will only become larger in what has been termed the "data explosion". To cater for this and the increased demands for increased data transmission speeds and lower latency, further development of cellular technology have been required.

The UMTS cellular technology upgrade has been dubbed LTE - Long Term Evolution. The idea is that 3G LTE will enable much higher speeds to be achieved along with much lower packet latency (a growing requirement for many services these days), and that 3GPP LTE will enable cellular communications services to move forward to meet the needs for cellular technology to 2017 and well beyond. The use of LTE will also provide the data capabilities that will be required for many years and until the full launch of the full 4G standards known as LTE Advanced.

TABLE 1 LTE and its Predecessors

	WCDMA (UMTS)	HSPA HSDPA/ HSUPA	HSPA+	LTE
Max downlink speed bps	384 k	14 M	28 M	100M
Max uplink speed bps	128 k	5.7 M	11 M	50 M
Latency round trip time approx	150 ms	100 ms	50ms (max)	~10 ms
3GPP releases	Rel 99/4	Rel 5 / 6	Rel 7	Rel 8
Approx years of initial roll out	2003 / 4	2005 / 6 HSDPA 2007 / 8 HSUPA	2008 / 9	2009 / 10
Access methodology	CDMA	CDMA	CDMA	OFDMA / SC-FDMA

TABLE 2 LTE Basic Specifications:

PARAMETER	DETAILS
Peak downlink speed 64QAM (Mbps)	100 (SISO), 172 (2x2 MIMO), 326 (4x4 MIMO)
Peak uplink speeds (Mbps)	50 (QPSK), 57 (16QAM), 86 (64QAM)
Data type	All packet switched data (voice and data). No circuit switched.
Channel bandwidths (MHz)	1.4, 3, 5, 10, 15, 20
Duplex schemes	FDD and TDD
Mobility	0 - 15 km/h (optimized), 15 - 120 km/h (high performance)
Latency	Idle to active less than 100ms Small packets ~10 ms
Spectral efficiency	Downlink: 3 - 4 times Rel 6 HSDPA Uplink: 2 -3 x Rel 6 HSUPA
Access schemes	OFDMA (Downlink) SC-FDMA (Uplink)
Modulation types supported	QPSK, 16QAM, 64QAM (Uplink and downlink)

LTE defines a number of channel bandwidths. Obviously the greater the bandwidth, the greater the channel capacity. The channel bandwidths that have been chosen for LTE are 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz

In addition to this the subcarriers spacing is 15 kHz, i.e. the LTE subcarriers are spaced 15 kHz apart from each other. To maintain orthogonality, this gives a symbol rate of 1/15 kHz = of 66.7 µs.

I. FUNDAMENTAL CONCEPTS OF LTE:

LTE has introduced a number of new technologies when compared to the previous cellular systems. They enable LTE to be able to operate more efficiently with respect to the use of spectrum, and also to provide the much higher data rates that are being required.

i. ***OFDM (Orthogonal Frequency Division Multiplexing):*** OFDM technology has been incorporated into LTE because it enables high data bandwidths to be transmitted efficiently while still providing a high degree of resilience to reflections and interference.

ii. ***SC-FDMA (Single Carrier - Frequency Division Multiple Access):*** SC-FDMA is used in the uplink in view of the fact that its peak to average power ratio is small and the more constant power enables high RF power amplifier efficiency in the mobile handsets an important factor for battery powerequipment.

iii. ***MIMO (Multiple Input Multiple Output):***One of the main problems that previous telecommunications systems has encountered is that of multiple signals arising from the many reflections that are encountered. By using MIMO, these additional signal paths can be used to advantage and are able to be used to increase thethroughput.

iv. ***SAE (System Architecture Evolution):***With the very high data rate and low latency requirements for 3G LTE, it is necessary to evolve the system architecture to enable the improved performance to be achieved. One change is that a number of the functions previously handled by the core network have been transferred out to the periphery. Essentially this provides a much "flatter" form of network architecture. In this way latency times can be reduced and data can be routed more directly to itsdestination.

The actual implementation of the technology will be different between the downlink (i.e. from base station to mobile) and the uplink (i.e. mobile to the base station) as a result of the different requirements between the two directions and the equipment at either end.The OFDM signal used in LTE comprises a maximum of 2048 different sub-carriers having a spacing of 15 kHz. Although it is mandatory for the mobiles to have capability to be able to receive all 2048 sub-carriers, not all need to be transmitted by the base station which only needs to be able to support the transmission of 72 sub-carriers. In this way all mobiles will be able to talk to any base station.For the LTE uplink, a different concept is used for the access technique. Although still using a form of OFDMA technology, the implementation is called Single Carrier Frequency Division Multiple Access (SC-FDMA).

One of the key parameters that affects all mobiles is that of battery life. Even though battery performance is improving all the time, it is still necessary to ensure that the mobiles use as little battery power as possible. With the RF power amplifier that transmits the radio frequency signal via the antenna to the base station being the highest power item within the mobile, it is necessary that it operates in as efficient mode as possible. This can be significantly affected by the form of radio frequency modulation and signal format. Signals that have a high peak to average ratio require linear amplification do not lend themselves to the use of efficient RF power amplifiers. As a result it is necessary to employ a mode of transmission that has as near a constant power level when operating. Unfortunately OFDM has a high peak to averageratio.

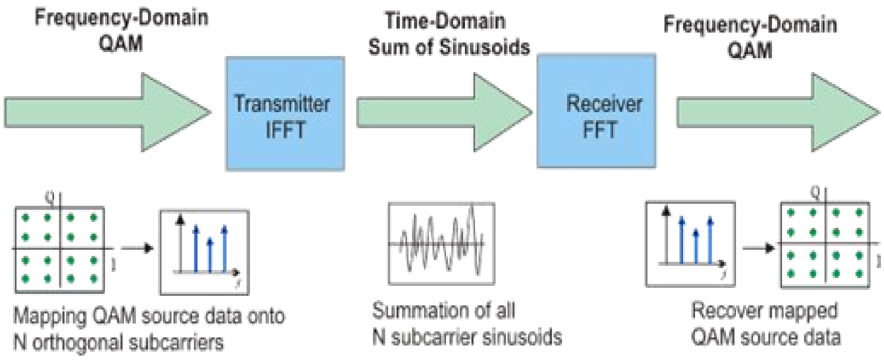


Figure: 1Simplified block diagram of OFDM

The PAPR is directly proportional to the square of number of sub-carriers present. While this is not a problem for the base station where power is not a particular problem, it is unacceptable for the mobile. As a result, LTE uses a modulation scheme known as SC-FDMA - Single Carrier Frequency Division Multiplex which is a hybrid format. This combines the low peak to average ratio offered by single-carrier systems with the multipath interference resilience and flexible subcarrier frequency allocation that OFDMprovides.

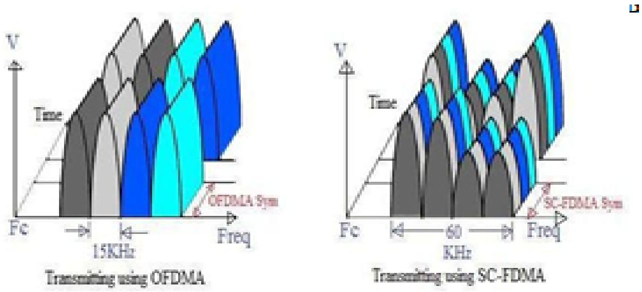


Figure: 2 SC-FDMA

High PAPR requires expensive and inefficient power amplifiers with high requirements on linearity, which increases the cost of the terminal and drains the battery faster. SC-FDMA solves this problem by grouping together the resource blocks in such a way that reduces the need for linearity, and so power consumption, in the power amplifier. A low PAPR also improves coverage and the cell-edge performance.The following figure is the OFDM transmitter used in LTE:

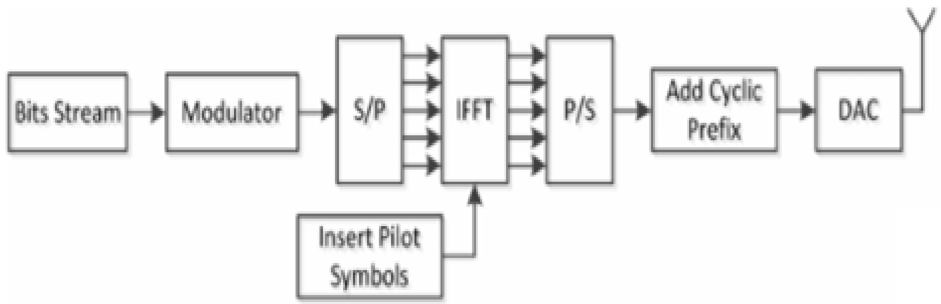


Figure: 3 Block diagram of OFDM Transmitter

II. IMPLEMENTATION IN LABVIEW:

Description of blockdiagram:

Serial to parallel converter(s/p) : The first OFDM block is the serial to parallel block which converts the bit stream into several blocks of variable number of bits and each of one will be modulated. The number of bits in each block depends on the modulation scheme used. In LTE the number of bits for each block can be two, four or six bits. Parallel bit-stream has an advantage of speed over serialtransmission.

ConstellationMapping *:* The second OFDM block is called the constellation mapping which converts the blocks of bits into modulated symbols. The modulation schemes defined for LTE are QPSK, 16 QAM and 64 QAM. The criterion to choose a specific modulation scheme rather than other will depend on communication channel quality in the frequency band of the sub-carrier carrying a specific modulated symbol.

SubcarrierMapping *:* The third OFDM block is called the sub-carrier mapping which consists in assigning the sub-carriers to the modulated symbols. Each sub-carrier can carry one modulated symbol each time. It is possible that some sub-carriers do not carry any modulated symbol.

N-PointIFFT: The fourth OFDM block is the N-point IFFT block which applies the Inverse Fast Fourier Transform to the modulated symbols already in the desired order. Usually the number of subcarriers carrying data is less than N. When this happens the input of the IFFT is fulfilled with zeroes in order to match the IFFTsize.

Cyclic Prefix*:* The fifth block is the cyclic prefix block which consists in adding samples to the N samples from the output of the IFFT. The number depends on the type of cyclic prefix used and on the sampling frequency. LTE cyclic prefix can have two lengths namely the normal cyclic prefix and the extended cycle prefix.

Parallel to Serial Converter(P/S) *:* The sixth block is the parallel to serial block and consists in converting the parallel samples from the output of the cyclic prefix clock into a discrete time sequence which represents the OFDM time discrete baseband signal.

Digital To Analog Converter(D/A)*:* The seventh block is the digital to analogue (D/A) block which converts the discrete time signal into an analogue/continuous timesignal.

Radio: The eighth block is called the Radio block which basically up converts the baseband signal to a radio frequency signal.

Critical Review of LabVIEW:

Lab VIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphical programming environment which has become prevalent throughout research labs, academia and industry. It is developed by National Instruments (NI) and is used for design, modeling, simulation, prototype testing, or deployment of new technologies.

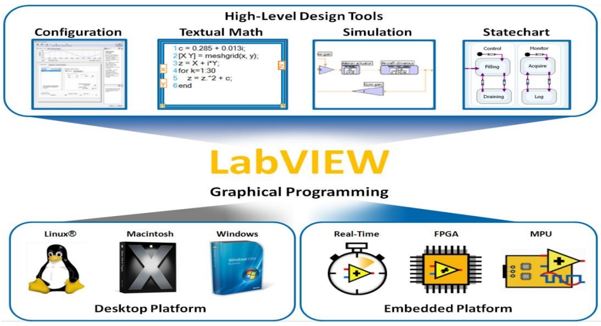


Figure: 4Design tools of LabVIEW

It is a powerful and versatile analysis and instrumentation software system for measurement and automation. Its graphical programming language called G programming is performed using a graphical block diagram that compiles into machine code and eliminates a lot of the syntactical details.

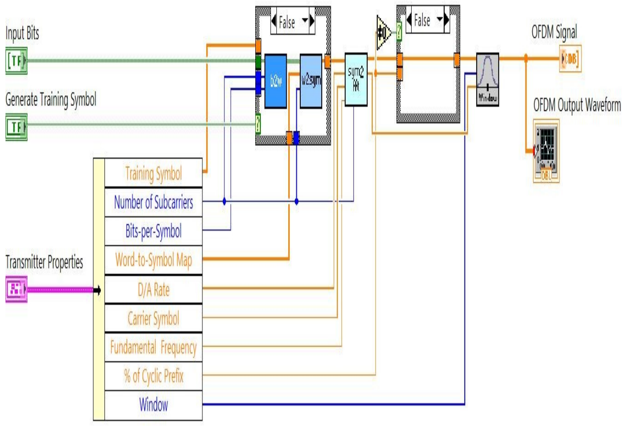


Figure: 5 VI for generating OFDM signal

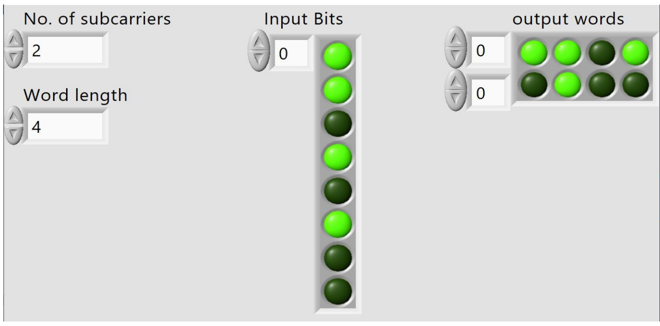
Various blocks of the LTE transmitter such as bits to words, constellation mapping, subcarrier mapping, IFFT etc., were designed and implemented using Lab VIEW.

III. RESULTS AND DISCUSSSIONS:

The input bits were converted to parallel words using the ‘b2w.vi’, these parallel words were mapped into symbols using a mapping table. The words can be modulated using different modulation schemes such as 4-QAM, 8-QAM… 64-QAM, etc., in the next step each symbol needs to be assigned a subcarrier for transmission. Assigning a subcarrier to each symbol and summing them is quite complex process, instead an Inverse Fast Fourier Transform (IFFT) is done to convert into time domain system. Zero padding is done before the transformation to ensure that the symbols are orthogonal to each other.

Cyclic prefix helps to eliminate Inter Symbol Interference (ISI) at the receiver. In practice, a normal cyclic prefix and an extended cyclic prefix is used. Effectively cyclic prefix adds a portion of the symbol from the end of the symbol to the beginning. The implementation enables a user to vary the percentage of signal to be prefixed. This signal may be windowed to avoid any discontinuities in the transmission. The 'window.vi' provides various windows to suit the application. Finally, all the previously implemented sub-VIs are used in the 'OFDMTX.vi' to complete the system.

Figure: 6 Test Input-1 for Bits-to-Words Block



The figure shows the output of the bits to words block with the number of sub carriers and the word length as 2 and 4 respectively, so an input of 8 bits is converted into two words of 4 bits each.

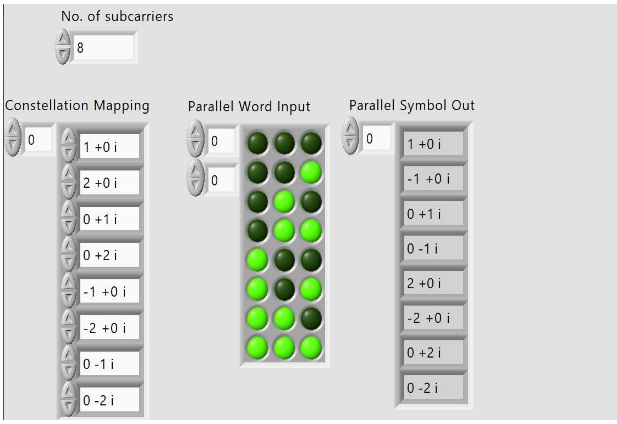


Figure 7 Test Input for Constellation Mapping Block Showing8-QAM.

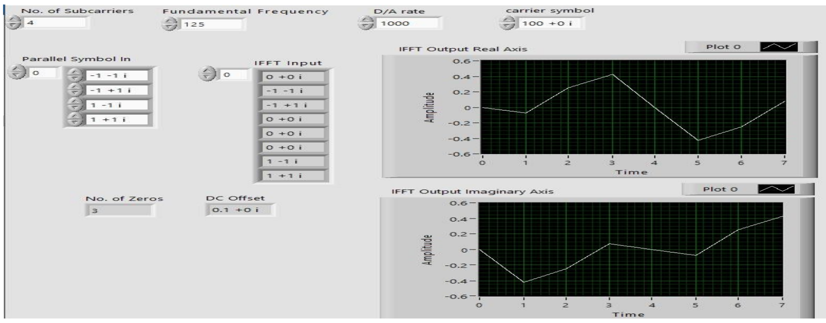


Figure: 8Test Input for Symbols-to-FFT Block with Fundamental Frequency as125Hz

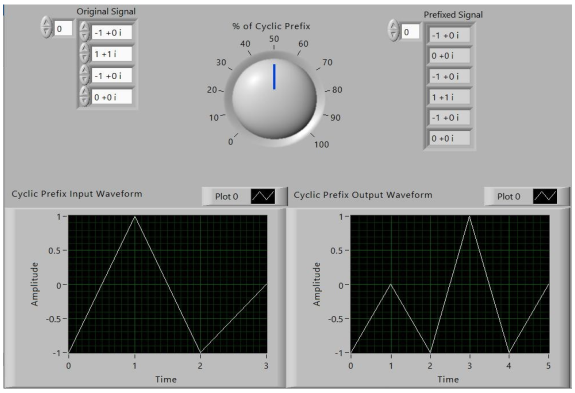


Figure:9Test Input for Cyclic Prefix block with 50%Prefix.

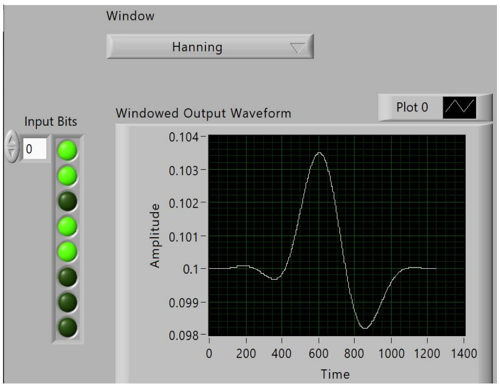


Figure: 10 Test input for Windowing Blockwith Hanning Window.

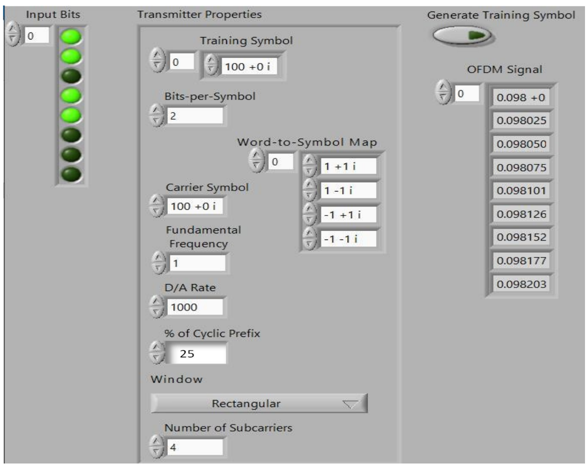


Figure: 11 Test Input to TransmitterBlock.

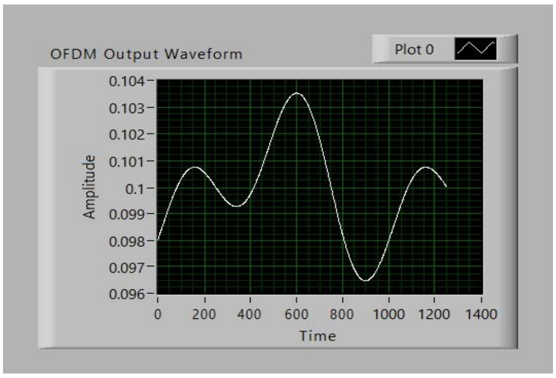


Figure: 12 OFDM signal output for the given test input in Lab VIEW.

CONCLUSION:

The OFDM transmitter is designed, implemented and tested in the LabVIEW (v2017) software. Various blocks of the transmitter such as bits to words, constellation mapping, subcarrier mapping, cyclic prefix etc., are individually implemented and finally all of them are combined to complete the system. Input test data is given to each implemented sub-VI to test its functionality and analyzed its output. Bits are converted to words, these words are converted to symbols and mapped to frequencies in a way that orthogonality is maintained. Cyclic prefix is added which would be helpful to eliminate ISI during reception. Signal variations with varying percentage of the cyclic prefix is observed. Effect of type of windowing techniques is also observed. Finally all the tested input parameters are given to the OFDM transmitter block and generated the OFDM signal.

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